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THE EVALUATION OF FEASIBILITY OF THERMAL ENERGY STORAGE SYSTEM AT RIGA TPP-2

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The installation of thermal energy storage system (TES) provides the optimisation of energy source, energy security supply, power plant operation and energy production flexibility. The aim of the present research is to evaluate the feasibility of thermal energy system installation at Riga TPP–2. The six modes were investigated: four for non-heating periods and two for heating periods. Different research methods were used: data statistic processing, data analysis, analogy, forecasting, financial method and correlation and regression method. In the end, the best mode was chosen – the increase of cogeneration unit efficiency during the summer.

Keywords: *heat storage system (TES), heat storage tank, modes, stratification.*

1. INTRODUCTION

Thermal energy storage system (TES) consists of a heat storage tank, storage medium, charging/discharging equipment and auxiliary equipment. Thermal energy storage system provides thermal energy collection and storage in order to use it later. Thermal energy storage system is described by thermal energy transfer from a heat source, energy transformation and heat transfer to consumers [1].

There are three goals of TES system installation that contribute to energy source performance optimisation [2], [3], [4]:

1. The thermal load levelling of heat energy source:

- Reduction of basic equipment start up and shutdown, thus extending the life-time of equipment;
- Basic equipment operation at higher load;
- Fuel consumption and fuel cost reduction;
- Replacement of inefficient and expensive equipment by a heat storage tank.

2. The increase of energy security supply:

- Continuous provision of consumers with heat energy, when equipment operation suddenly is interrupted or during the launching of emergency equipment;

- Support of district heating system pressure and temperature during unexpected situations. In case of district heating system damages, the heat storage tank can be emptied. Moreover, the heat storage tank can be used as an expansion tank.

3. The increase of flexibility of energy source operation:

- Flexible energy generation according to electricity price fluctuations in the Nord Pool Spot (NPS) market;
- Temporary interruption of P/Q (electricity and heat load) ratio;
- Combination of different energy sources.

Commonly thermal energy storage systems are used in Denmark. Firstly, Denmark has appropriate climatic conditions, which make it possible to operate the thermal energy storage system during the whole year. Secondly, the European Union strategy implementation is to replace fossil fuels by renewable energy till 2050. Partly, thermal energy systems are used in Sweden. In Latvia, TES systems are not widely used; however, they are constructed and used in some energy sources [3].

Taking into account the goals and examples of thermal energy system installation in Europe and Latvia, the TES system installation at Riga TPP–2 is investigated in the present research.

2. CHOICE OF TES SYSTEM

There are three TES system groups: sensible, latent and thermochemical thermal energy storage. Usually the sensible thermal energy storage system is used, because it is the cheapest and easy-to-use one. The thermal energy accumulates by changing storage medium temperature. There are two thermal energy storage media: liquefied and solid. Thermal oils, molten salts and water are used in TES systems with liquefied storage medium. Such materials as rock, concrete, sand, bricks or metal are used in TES systems with solid medium. The TES with water medium has been chosen, because water is widely available, inexpensive, has good thermal energy storage properties and is not chemically active. The disadvantage of this medium is that it evaporates at the temperature of 100 ^{o}C [1], [2], [5].

The thermal energy storage system with thermal energy displacement is chosen. It means that hot and cold water are in the same tank. The thermal energy accumulates directly; thus, the heat storage tank is not equipped with warming elements. In this case, water is the thermal energy storage medium and thermal energy exchange medium. The operation of such TES system is based on water stratification in a heat storage tank – the hot water is at the top of the storage tank and the cold water is at the bottom of the storage tank due to water density difference. The stratification phenomenon is of great importance, because the levelling of water temperature inside the heat storage tank leads to the loss of useful heat storage tank volume (Fig. 1). Therefore, the provision of water stratification inside the heat storage tank increases the efficiency of TES system operation [6].

For example, the best water stratification is in a heat storage tank (a), because there is a greater temperature gradient than in a storage tank (b). That is why thermocline is thicker in the tank (a) than in the tank (b). The water temperature levelling is noticed in the heat storage tank (c) that is why there is no water stratification inside the tank (Fig. 1).

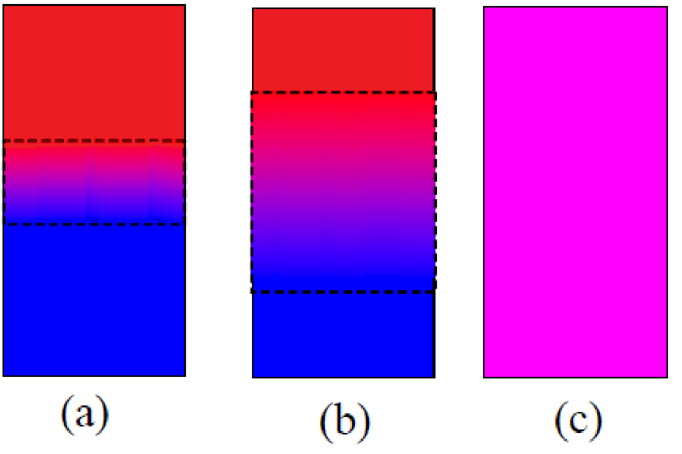

Fig. 1. Water stratification in heat storage tanks (a), (b), (c) [6].

There are many mechanisms, which destroy water stratification in the heat storage tank. On the other hand, there are many methods to improve the formation of water stratification in the heat storage tank. These methods are not considered in the present research, because it is a separate research theme.

The TES system with a vertical heat storage tank position is selected. Firstly, it allows for external conditions. Secondly, from the viewpoint of thermal energy storage the TES system with a vertical heat storage tank position is better than TES system with a horizontal storage tank position [7].

The selection of thermal energy storage system is dependent on heat energy storage period length, operating conditions, costs etc. [2]

3. DESCRIPTION OF INVESTIGATED MODES

One technological solution can provide a number of alternatives. By comparing them, the best alternative is chosen. Thus, six thermal energy storage system modes have been investigated in the present research (Table 1).

TES system modes have been investigated for two periods: heating and non–heating periods. Four modes have been explored for a non–heating period: the levelling of thermal load, when water heating boilers are in operation (Mode No. 1) or a cogeneration unit is in operation (Mode No. 2); increase of cogeneration unit operation efficiency in the summer (Mode No. 3); reduction of hypothetical biomass boiler construction costs (Mode No. 4). Two modes of TES system have been explored for a heating period: adjustment to electricity price fluctuations in the NPS market with a cogeneration unit shut down at night (Mode No. 5) or its output reduction at night (Mode No. 6). TES system possible benefits and limitations are different, because they depend on modes.

Table 1

Summary of Investigated Modes

Modes	1.	2.	3.	4.	5.	6.
Periods	Non-heating period (summer period)				Heating period	
TES goals	Thermal load levelling		The increase of cogeneration unit operation efficiency in the summer	Reduction of hypothetical biomass boiler construction costs	Adjustment to electricity price fluctuations in the NPS market	
					with a cogeneration unit shutdown at night	with a cogeneration unit load reduction at night
Equipment	Cogeneration unit + heat storage tank	Water heating boiler + heat storage tank	Cogeneration unit + heat storage tank	Biomass water heating boiler + heat storage tank	Cogeneration unit + water heating boiler + heat storage tank	
Possible benefits	Fuel consumption and CO_2 emission production reduction		Fuel consumption and CO_2 emission production reduction Profit from electricity trading	Reduction of biomass boiler construction costs District heating security	Profit from electricity trading	
Possible limitations	Insignificant thermal load fluctuations		Frequent cogeneration unit start up/shutdown	The probability of project implementation	Frequent cogeneration unit start up/shutdown	Ineffective cogeneration unit operation mode

4. DESCRIPTION OF THERMAL STORAGE SYSTEM EVALUATION ALGORITHM

The evaluation algorithm of the thermal storage system was created to investigate six modes of TES system (Fig. 2).

The algorithm consists of eight steps:

1. Reliable data acquisition and processing;
2. Definition of thermal storage system periods: heating or/and non-heating period;
3. Definition of TES system modes;
4. Determination of investments, revenues, costs. If costs are higher than revenues (negative result), then the study of such a mode is suspended. If revenues are higher than costs (positive result), then the study of this mode is continued.

5. Development of mode production programmes, which provide positive results in the algorithm fourth step;
6. Determination of mode economic indicators: payback time, Internal Rate of Return (IRR) and Net Present Value (NPV). Sensitivity analysis is performed;
7. Modes with a positive result in the fourth step are compared to the results obtained in the algorithm sixth step;
8. In the end, after the comparison of modes the best mode is chosen.

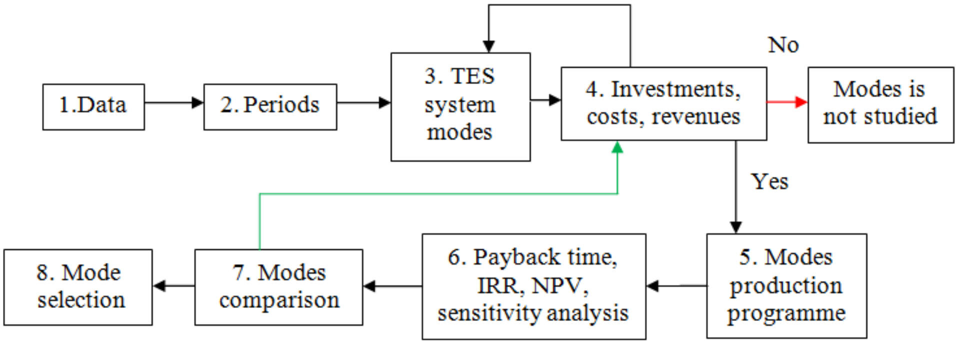

Fig. 2. TES system evaluation algorithm.

5. COMPARISON OF INVESTIGATED MODES AND THE BEST MODE CHOICE

The estimate of Mode No. 1 and No. 2 has been spotted in the fourth step of the evaluation algorithm of thermal energy storage system (Fig. 2). According to the calculations performed, it has been found that the water heating boilers and cogeneration unit heat load levelling during the summer do not benefit. In case of water heating boilers (Mode No. 1), natural gas saving is about $0.1^{x}10^{3}$ m^3 per day, if two water heating boilers are in operation. The benefits are not obtained, if one water heating boiler is in operation. In case of a cogeneration power unit (Mode No. 2), after thermal load levelling natural gas consumption increases by $0.5^{x}10^{3}$ m^3 per day.

Below, the remaining modes (No. 3, 4, 5, 6) are compared by TES basic parameters, economic indicators and by the results of production programme and sensitive analysis. The comparison of mode advantages and disadvantages is also provided.

A. Mode Comparison by TES System Basic Parameters

The accumulated heat energy amount proportionally influences heat storage tank volume and project investments (Fig. 3).

Figure 3 shows that Mode No. 5 (adjustment to the NPS market with cogeneration unit shutdown at night) and Mode No. 3 (increase of cogeneration unit efficiency in the summer) ensure the opportunity of reconstructing and using HFO tanks as heat storage tanks. Both tanks (No. 5 and No. 6) are located at Riga TPP-2. The reconstruction of two HFO tanks is necessary for Mode No. 5 and the reconstruction of one HFO tank is required for Mode No. 3. In case of Mode No. 4 (hypothetical biomass boiler construction) and Mode No. 6 (adjustment to the NPS market with a cogeneration load decrease at night) the new heat storage tank installation is necessary.

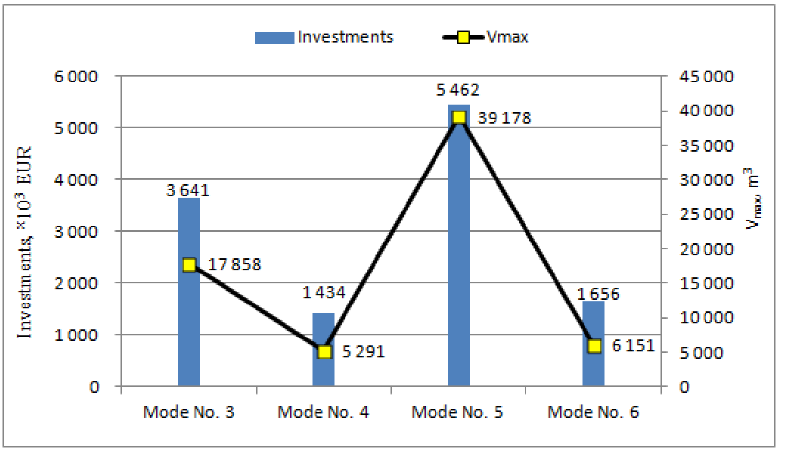

Fig. 3. Mode comparison by TES system parameters.

Figure 3 shows that capital investments in Mode No. 5 and Mode No. 3 are greater than capital investments in Mode No. 4 and Mode No. 6. Thus, it is more expensive to build a new heat storage tank than to reconstruct HFO tanks as heat storage tanks.

B. Calculation of Mode Return of Investments

The mode payback time was calculated at the discount rate of 9 %. Table 2 shows that the best mode is Mode No. 3, which provides the increase of cogeneration unit efficiency in the summer. This mode payback time is 3.5 years, IRR is 32.3 % for the 10^{th} year and NPV is 4397.9×10^3 EUR for the 10^{th} year.

Table 2

Calculation of Mode Return of Investments

Indicators	Unit	Mode No. 3	Mode No. 4	Mode No. 5	Mode No. 6
Discounted payback time	year	3.5	6.5	9.3	> 20
NPV for the 10^{th} year	$\times 10^3$ EUR	4397.9	506.1	258.4	-1 270.7
NPV for the 15^{th} year	$\times 10^3$ EUR	6456.1	981.6	1722.8	-1 171.9
IRR for the 10^{th} year	%	32.3 %	16.5 %	10.1 %	-
IRR for the 15^{th} year	%	34.0 %	19.5 %	14.0%	-

Mode No. 3 is followed by Mode No. 4 – reduction of hypothetical biomass boiler construction costs. The mode payback time is 6.5 years, IRR is 16.5 % and NPV is 506.1$^{x}10^{3}$ EUR for the 10th year.

Then Mode No. 5 follows (adjustment to the NPS market with a cogeneration unit shutdown at night), which is close to being not cost-effective. The mode payback time is 9.3 years, NPV is 258.4$^{x}10^{3}$ EUR and IRR – 10.1 % for the 10th period. Mode No. 6 (adjustment to the NPS with a cogeneration unit load reduction at night) is not profitable. The mode payback time is greater than 20 years and NPV is negative for the 10th and 15th year (Table 2).

C. Comparison of Mode Production Programmes

In case of Mode No. 5 and No. 6, the TES system can be used for 31 days longer compared to Mode No. 3. As modes differ by performance and implementation period (heating and non-heating period), that is why accumulated thermal energy amount, purchased and sold electricity amount differ, too (Table 3). For example, Mode No. 5 can accumulate 3.3 times more than Mode No. 3 and 7.3 times more than Mode No. 6. Thus, Mode No. 5 ensures additional electricity production approximately 11.0 times more than Mode No. 3 and 7.3 times more than Mode No. 6. In case of Mode No. 3, electricity production is about 1.4 times lower and in case of Mode No. 6 about 11.7 times lower than in Mode No. 5. Just Mode No. 3 promotes reduction of natural gas consumption and CO_2 emission production, because the heat energy amount required at night is produced during a day with the highest efficiency (η = 88.2 %) than at night (η = 64.7 %).

Table 3

Comparison of Mode Production Programmes

Indicators	Units	Mode No. 3	Mode No. 5	Mode No. 6
Days	amount	92	123	123
Accumulated thermal energy	MWh	34 058	113 154	15 310
Purchased electricity	MWh	67 564	95 853	8 190
Additional sold electricity	MWh	25 658	282 951	38 744
Decrease of natural gas consumption	$^{x}10^{3}$ m^3	7 154.1	- 24 427.6	- 4 736.1
Reduction of CO_2 emissions	t	13 473	- 45 858	- 8 901

Mode No. 5 and Mode No. 6 do not ensure the decrease of natural gas consumption and CO_2 emission production. According to Mode No. 5, the additional electricity production is 11.7 times higher and the accumulated heat energy amount is 7.3 times higher than that provided by Mode No. 6. That is why in case of Mode No. 5 natural gas is consumed and CO_2 emissions are produced 5.1 times more.

Mode net present value is represented in Fig. 4.

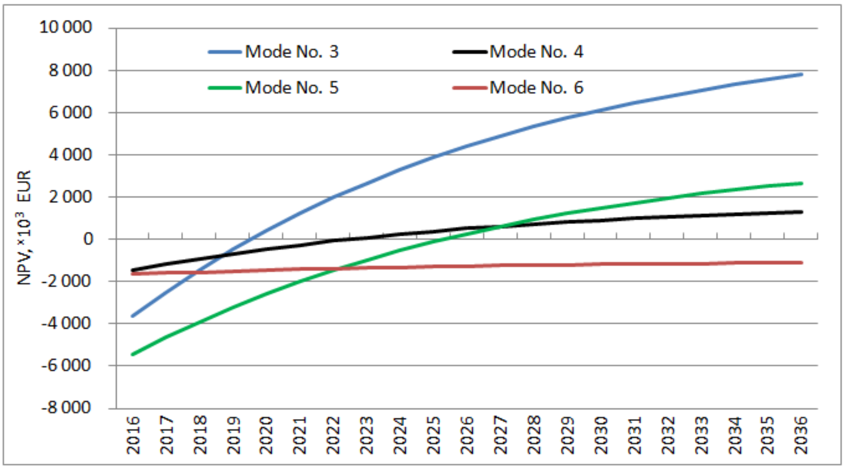

Fig. 4. Net present value of modes No. 3, 4, 5, 6.

From four modes, Mode No. 3 (the increase of cogeneration unit efficiency in the summer) stands out. This mode ensures faster money accumulation than other modes with its rapid generation in future. In case of Mode No. 4, the NPV curved line grows faster than in case of Mode No. 5. Thus, the NPV curve of Mode No. 5 advances the curve of Mode No. 4 in the 12th year from the project start time. Mode No. 6 does not generate money saving (Fig. 4).

D. Mode Sensitivity Analysis – Increase of Natural Gas Price by +10 %

Figure 4 represents (the reduction of hypothetical biomass boiler construction costs) that the natural gas price increase has an insignificant influence on the efficiency of Mode No. 4, because this mode mainly provides the use of wood chips. Natural gas is expected to be used in case of a sudden biomass boiler shutdown (Table 4).

However, the increase of natural gas price significantly impacts other modes. Mode No. 5 becomes unprofitable – the payback time is more than 20 years and NPV is negative for the 10th and 15th year. The economic indicators of Mode No. 6 become worse.

Table 4

Result Summary of Sensitivity Analysis

Indicators	Mode No. 3	Mode No. 4	Mode No. 5	Mode No. 6
Discounted payback time, years	4.2	6.6	> 20	> 20
NPV for the 10th year, $^{\times}10^3$ EUR	916.3	446.0	- 31 6616.1	- 5 482.6
NPV for the 15th year, $^{\times}10^3$ EUR	-873.7	855.2	- 65 486.6	- 10 039.1
IRR for the 10th year, %	17.8	15.8	-	
IRR for 15th year, %	-	18.6	-	-

In case of Mode No. 3, the mode payback time increases just only by 1.3 years, but project implementation time decreases, because NPV decreases from the project 9th year and becomes negative in the project 14th year.

E. Mode Sensitivity Analysis – Difference between Electricity Day and Night Prices (△C)

Table 5 shows that △C increase or decrease impacts more Mode No. 5 and Mode No. 6 than Mode No. 3. The economic indicators of Mode No. 6 become better with △C increase by 5 EUR/MWh. Nevertheless, Mode No. 5 becomes unprofitable with △C increase by 5 EUR/MWh.

Table 5

Summary of Sensitivity Analysis Results

Indicators	Mode No. 3	Mode No. 5	Mode No. 6
△C decrease by 5 EUR/MWh			
Discounted payback time, years	3.9	>20	>20
NPV for the 10th year, $^{x}10^{3}$ EUR	3 698.7	-7 427.7	-2 374.3
NPV for the 15th year, $^{x}10^{3}$ EUR	5 577.8	-7 931.1	-2 558.1
IRR for the 10th year, %	28.9	-	-
IRR for the15th year, %	30.9	-	-
△C increase by 5 EUR/MWh			
Discounted payback time, years	3,2	3.1	13.3
NPV for 10th year, $^{x}10^{3}$ EUR	5 098.4	8 005.7	-254.3
NPV for 15th year, $^{x}10^{3}$ EUR	7 335.8	11 453.5	104.7
IRR for the 10th year, %	35.6	36.7	5.4
IRR for the 15th year, %	37.1	38.1	10.1

In case of △C decrease and increase, the payback time of Mode No. 3 increases or decreases by less than half a year. Correspondingly, IRR for the 10th year decreases by 3.4 % and NPV decreases by $699.2^{x}10^{3}$ EUR with △C reduction by 5 EUR/MWh. But △C increase by 5 EUR/MWh ensures the increase of IRR by 3.3 % for the 10th year and NPV increases by $700.5^{x}10^{3}$ EUR (Table 5).

F. Mode Sensitivity Analysis – Increase of HFO Tank Reconstruction Costs

Sensitivity analysis of increase of HFO tank reconstruction costs was carried out for Mode No. 3 (cogeneration unit efficiency increase in the summer) and No. 5 (adjustment to the NPS with a cogeneration unit shutdown at night). It has a negative impact on both modes. But it is less noticeable in case of Mode No. 3 than in case of Mode No. 5. Increase of reconstruction costs by 667.5^{x}10^{3} EUR (one HFO tank) provides the increase of payback time of Mode No. 3 by less than a year, NPV increase by 829.4^{x}10^{3} EUR and IRR increase by 6.7 % for the 10th year (Table 6).

Table 6

Results of Sensitivity Analysis

Indicators	Mode No. 3	Mode No. 5
*Basic calculation (one HFO tank – 3641.0 *10^{3} EUR and two HFO tanks – 5461.5 *10^{3} EUR)*		
Discounted payback time, years	3.5	9.3
NPV for the 10th year, ^{x}10^{3} EUR	4 397.9	258.4
NPV for the 15th year, ^{x}10^{3} EUR	6 456.1	1 722.8
IRR for the 10th year, %	32.3	10.1
IRR for the 15th year, %	34.0	14.0
*Investments increase (one HFO tank – 4308.5 *10^{3} EUR and two HFO tanks – 6463.0 *10^{3} EUR)*		
Discounted payback time, years	4.4	14.8
NPV for the 10th year, ^{x}10^{3} EUR	3 568.5	-1 286.2
NPV for the 15th year, ^{x}10^{3} EUR	5 585.2	39.2
IRR for the 10th year, %	25.6	4.2
IRR for the 15th year, %	27.8	9.1

After HFO tank reconstruction costs increase by 1001.5$^{\times}$10^{3} EUR (two HFO tanks), Mode No. 5 becomes close to being not cost-effective. The payback time increases by 5.5 years, NPV becomes negative for the 10th year and IRR becomes less than 9 %. But then NPV decreases by 1683.6$^{\times}$10^{3} EUR for the 15th year and IRR is 9.1 % for the 15th year (Table 6).

G. Sensitivity Analysis of Mode No. 4

The sensitivity analysis for Mode No. 4 (reduction of construction costs of hypothetical biomass water heating boiler) was carried out by the following variables: decrease of biomass boiler construction costs by 2500^{x}10^{3} EUR, increase of construction costs by 2500^{x}10^{3} EUR and increase of wood chip price by + 10 % (Table 7).

Table 7

Sensitivity Analysis of Mode No. 4

Discounted payback time, years	NPV for the 10th year, ^{x}10^{3} EUR	NPV for the 15th year, ^{x}10^{3} EUR	IRR for the 10th year, %	IRR for the 15th year, %
Construction costs of hypothetic biomass water heating boiler decrease by 2500x10^{3} EUR (Construction costs 10 000x10^{3} EUR)				
4.4	1 188.0	1 838.1	25.6	27.7
Construction costs of hypothetic biomass water heating boiler increase by 2500x10^{3} EUR (Construction costs 5 000x10^{3} EUR)				
12.7	-175.7	125.2	6.1	10.5
Chip price increase by +10 %				
6.4	530.8	1 033.6	16.8	19.9

Reduction of biomass water heating boiler construction costs by $2500^x 10^3$ EUR decreases mode payback time by 2.1 years, increases NPV by 2.3 times and IRR by 1.6 times for the 10th year. On the other hand, with an increase of biomass boiler investments costs by $2500^x 10^3$ EUR, the mode becomes close to being unprofitable. Thus, mode repayment time increases by two times, NPV becomes negative and IRR becomes lower than 9 % for the 10th year (Table 7).

Table 8 represents the advantages and disadvantages of modes according to the results of comparison as well as to other considerations.

Table 8

Comparison of Mode Advantages and Disadvantages

Modes	Advantages	Disadvantages
Mode No. 3	Providing the best economic indicator values – short payback time, high IRR and NPV values; Change of electricity price in the NPS market and increase of HFO tank reconstruction costs have an insignificant influence on mode profitability; Possibility to operate a cogeneration unit during the summer; Reduction of natural gas consumption and CO_2 emissions; Opportunity to reconstruct one HFO tank as a heat storage tank.	Frequent cogeneration unit start up/shutdown reduces the operation time of a cogeneration unit; Possibility not to start up a cogeneration unit after its shutdown; Increase of natural gas price reduces project implementation time; Inefficient (reserve) extra accumulated heat energy use.
Mode No. 4	The lowest investments; Fluctuations of natural gas and wooden chip prices have no significant impact on mode profitability; Use of renewable energy source.	At present, the project of biomass boiler construction evaluation has shown that it cannot be implemented; Increase of biomass boiler construction costs significantly impacts mode profitability; Heat energy production only (no electricity production).
Mode No. 5	Opportunity to reconstruct HFO tanks as a heat storage tank; Possibility to improve cogeneration unit operation at night (natural gas price is constant); Additional profit from electricity trading in the NPS market (natural gas price is constant).	Large investments; Mode is close to being unprofitable; Mode becomes not cost-effective with natural gas price increase and $\triangle C$ decrease; The increase of HFO tank reconstruction costs negatively influences mode profitability; Frequent cogeneration unit start up/shutdown reduces the operation time of cogeneration unit; Possibility not to start up cogeneration after its shutdown; Additional natural gas consumption and CO_2 emission.
Mode No. 6	$\triangle C$ increase prevents mode from being unprofitable, so the mode becomes close to being not cost-effective.	It is not efficient to reduce a loading cogeneration unit at night; Dependence on natural gas price increase and $\triangle C$ decrease; Additional natural gas consumption and CO_2 emissions.

6. THE BEST MODE CHOICE

The best mode is Mode No. 3 – the efficiency increase of a cogeneration unit in the summer. This mode has fewer risks and is more beneficial than other modes.

Mode No. 4 (reduction of hypothetical biomass boiler construction costs) also provides good results. There is still no final decision about biomass boiler construction that is why Mode No. 3 should definitely be selected.

A. The Heat Storage Tank Location

It is not necessary to construct a new heat storage tank. Mode No. 3 ensures the opportunity to use one of HFO tanks (No. 5 or No. 6). HFO tank No. 6 is selected, because it is located close to cogeneration unit 2/1 and 2/2 than HFO tank No. 5.

B. Heat Storage Tank Connection Schemes

The pipeline system of Riga TPP-2 has a special feature. The CHP-2/1 and CHP-2/2 outputs are directed to a hot water boiler house. Thus, there are two options how to connect the reconstructed HFO tank to TPP-2 pipeline system (Fig. 5 and Fig. 6).

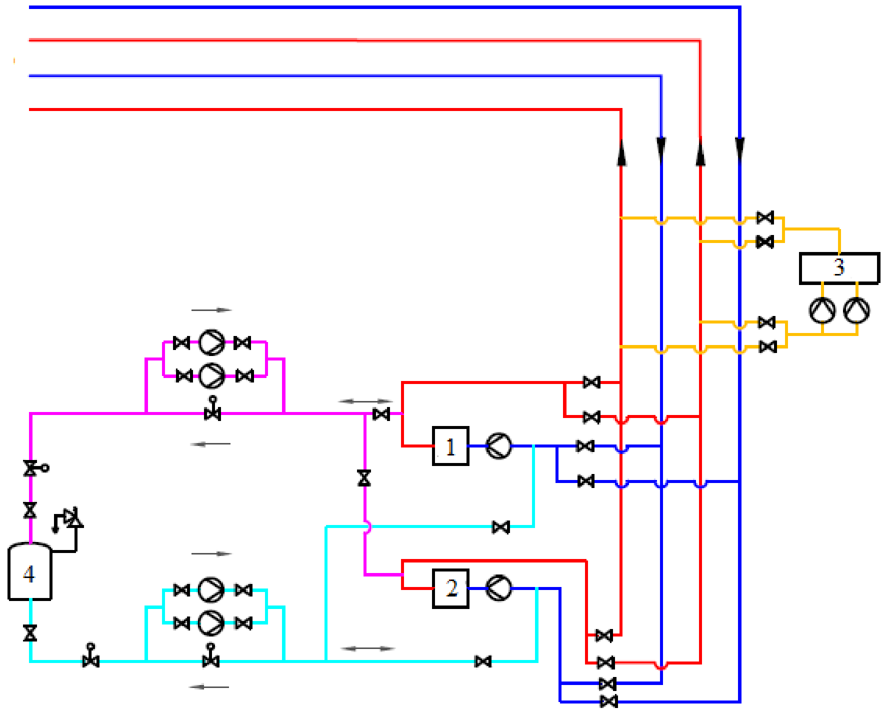

Fig. 5. Connection of HFO No. 6 to cogeneration unit pipeline inlets/outlets (1. CHP-2/1; 2. CHP-2/2; 3. Water heating boiler house; 4. HFO tank No. 6).

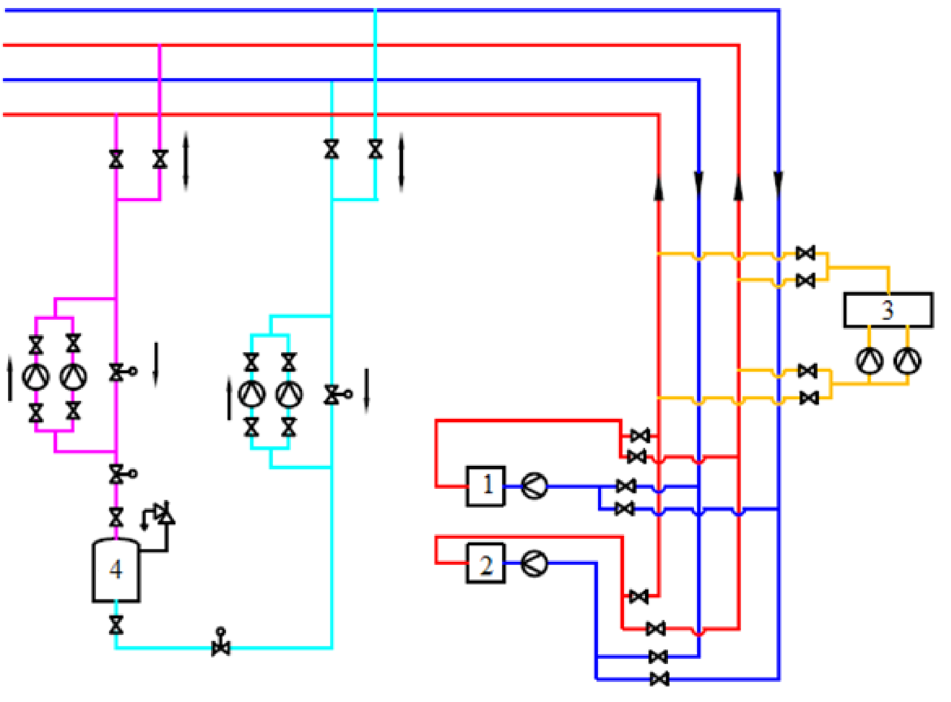

Fig. 6. Connection of HFO tank No. 6 to the main pipelines
(1. CHP-2/1; 2. CHP-2/2; 3. Water heating boiler house; 4. HFO tank No. 6).

The first connection scheme ensures the HFO tank connection to the both cogeneration power unit pipe outlets/inlets, because only one cogeneration unit works during the summer (CHP-2/1 or CHP-2/2) (Fig. 4).

The second connection scheme provides the opportunity of HFO tank connection to the main pipelines until the zone covered by *Rigas Siltums* (Fig. 5). In this case, the commercial metering of produced heat energy is necessary.

Both connection schemes provide reconstructed HFO tank equipment with one cold water inlet/outlet and hot water inlet/outlet. The heat storage charging and discharging with hot water occur along a line (A). During the hot water discharging process the bypass is used. The heat storage charging and discharging with cold water occur along a line (B). During the cold water discharging process the bypass is used (Fig. 4 and Fig. 5).

C. Heat Losses from Heat Storage Tank Outer Surface

Evaluating heat losses from heat storage tank outer surface, it has been found that heat losses are negligible in comparison with the whole system. The amount of losses is 1.5 MWh for the summer period. Thus, additional natural gas consumption is 16 771 m^3 (5558 EUR). Also, the additionally produced CO_2 emissions are about 31.5 t (126 EUR) for the summer period.

7. HFO TANK RECONSTRUCTION AS HEAT STORAGE TANKS

At Riga TPP-2, heavy fuel oil was used as emergency fuel. It was stored in four 20000 m^3 (4×20000 m^3) tanks. Two HFO tanks were reconstructed and now are used to store diesel fuel as emergency fuel. The other two tanks No. 5 and No. 6 are not in use that is why it is possible to reconstruct them as heat storage tanks [8].

The study initially has shown five obstacles that can complicate the reconstruction of heavy oil fuel tanks as heat storage tanks:

1. The technical condition of reservoir;
2. The maximum water temperature;
3. The insulation of HFO bottom part;
4. Inappropriate H/D ratio (small);
5. Heavy fuel oil removal from tank.

The HFO tanks as dangerous equipment take tests with occupational health and safety inspection and evaluation equipment experts. After the last heavy fuel oil tank inspection and survey, it has been found that the tanks can be used and deviations have not been found. Only HFO tank insulation and metal coating should be replaced.

The water starts boiling at a temperature of 100 °C that is why tanks must be held under pressure (pressurised tank). To avoid the use of pressurised tank, the water at temperature till 95 °C should be stored. Existing heavy fuel oil tanks were designed to store heavy fuel oil at the temperature of 90 °C. Thus, the heavy fuel oil tanks can be used as heat storage tanks until the temperature of 90 °C.

Difficulties may cause the tank bottom part insulation. It is placed on a concrete base, which is good heat conduction material; therefore, the bottom part should be insulated. It is difficult to set external insulation because the bottom of the HFO tanks should be replaced. Thus, it is proposed to use internal insulation.

The H/D of HFO tanks is 0.4, which does not correspond to optimal H/D, that can cause non-optimal stratification in heat storage tanks. The optimal H/D ratio is 3–4. In order to reduce the losses of turbulence mixing, it is proposed to use the diffuser to reduce inlet/outlet water velocity.

Now the heavy fuel oil is in tanks No. 5 and No. 6. The tanks must be cleaned in order to use them as heat storage tanks. The process of HFO tank purification is expensive and complex that can increase project costs and has a negative effect on the project economic assessment.

8. CONCLUSION

According to Latvian climatic conditions, the heat storage system is mainly used to level the thermal load and to increase energy supply security during the summer. At Riga TPP, the heat storage system installation is required to increase the efficiency of cogeneration power unit during the summer. This mode provides one HFO tank reconstruction as a heat storage tank. This mode also ensures the natural gas saving (7154.1×10^3 m^3) and CO_2 emission reduction (13472 t). Moreover, this mode has the best economic indicator values. The electricity price fluctuations in the Nord Pool Spot and the increase of HFO tank reconstruction costs have little impact on the profitability of the regime. Due to the increase of natural gas price, the mode becomes unprofitable in the 14th year of the project life.

The implementation of the other modes at Riga TPP-2 is not economically justified or mode implementation is limited by external factors. For example, the thermal load levelling during the summer period (Mode No. 1 and No. 2) is useless due to small heat load fluctuations. The load reduction of a cogeneration unit at night is less efficient than a cogeneration unit shutdown at night. By contrast, external factors (increase of natural gas price and HFO reconstruction costs, fluctuations of electricity price) significantly influence the profitability of the fifth mode. Mode 4 (reduction of hypothetical biomass boiler construction costs) is the second best mode, which has prospects of development in future with the biomass boiler construction on the right bank of the Daugava River in Riga district heating system.

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SILTUMA AKUMULĀCIJAS SISTĒMAS UZSTĀDĪŠANAS LIETDERĪGUMA NOVĒRTĒJUMS RĪGAS TEC-2

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K o p s a v i l k u m s

Pētījuma mērķis novērtēt siltuma akumulācijas sistēmas uzstādīšanas lietderīgumu Rīgas TEC-2, salīdzinot režīmus ar jaunu siltuma akumulācijas tvertnes uzstādīšanu ar režīmiem, kas paredz TEC-2 teritorijā esošo mazuta rezervuāru re-

konstrukciju par siltuma akumulācijas tvertnēm. Seši siltuma akumulācijas sistēmas režīmi tiek apskatīti. Četri režīmi tiek apskatīti ārpus apkures perioda: siltuma slodzes izlīdzināšana, ja strādā koģenerācijas energobloks (1. režīms) vai ūdens sildāmie katli (2. režīms); palielināt koģenerācijas energobloka darbības efektivitāti vasaras periodā (3. režīms); samazināt hipotētiskā biomasas katla uzstādīšanas izmaksas un palielināt siltuma apgādes drošumu (4. režīms); pielāgošana elektroenerģiju svārstībām NPS biržā ar koģenerācijas energobloka pilnīgu apturēšanu naktī (5. režīms) vai ar koģenerācijas energobloka jaudas samazināšanu naktī (6. režīms).

Sešu režīmu pētīšana tika veikta pēc siltuma akumulācijas sistēmas vērtējuma algoritma, kas paredz: datu iegūšanu; režīmu izvēli; investīciju, izmaksu, ieņēmumu noteikšanu; ražošanas programmas sastādīšanu; atmaksāšanas laika, IRR, NPV aprēķināšanu; jūtīguma analīzi; režīmu salīdzinājumu un labākā režīma izvēli. Dažādas pētījuma metodes tiek pielietotas: analīze, datu statistiskā apstrāde, analoģija, prognozēšana, korelācija un regresijas metode, modelēšana, finansiālas rentabilitātes metode, u.c.

Pamatojoties uz pētījuma rezultātiem, labākais režīms ir trešais režīms, kas nodrošina koģenerācijas energobloka efektivitātes palielināšanu vasaras periodā. Arī trešais režīms paredz iespēju rekonstruēt vienu mazuta rezervuāru kā siltuma akumulācijas tvertni. Siltuma slodzes izlīdzināšana vasaras periodā nav pamatota, nelielu siltuma slodžu fluktuāciju dēļ. Koģenerācijas energobloka slodzes samazināšana ir efektīvāka par to jaudas samazināšanu nakts laikā, bet dabas gāzes cenas kāpums negatīvi ietekmē režīmu ar koģenerācijas energobloka jaudas samazināšanu, samazinot to realizācijas laiku.

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